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416 Rec'd PCT/PTO 09 MAR 2000

FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5)
23815 USA	09/508322

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB98/02526	21 August 1998	9 September 1997

TITLE OF INVENTION
DISC BRAKE ROTOR WITH A GREY CAST IRON COMPOSITION

APPLICANT(S) FOR DO/EO/US
John D. Holme

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☒ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Abstract
British Search Report under Section 17 dated 5 November 1988
British Search Report under Section 17 dated 4 November 1997
1 page Form PTO-1449 and 11 References included with IDS

PCTUS1/REV03

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/508522	PCT/GB98/02526	23815 USA

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS PTO USE ONLY
☐	Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$970.00**
☒	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO	**$840.00**
☐	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$690.00**
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$670.00**
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)	**$96.00**

ENTER APPROPRIATE BASIC FEE AMOUNT = **$840.00**

Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). **$0.00**

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	8 - 20 =	0	x $18.00	**$0.00**
Independent claims	1 - 3 =	0	x $78.00	**$0.00**
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**

TOTAL OF ABOVE CALCULATIONS = **$840.00**

Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable).** ☐ **$0.00**

SUBTOTAL = **$840.00**

Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). + **$0.00**

TOTAL NATIONAL FEE = **$840.00**

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☒ **$40.00**

TOTAL FEES ENCLOSED = **$880.00**

Amount to be: refunded $

charged $

☒ A check in the amount of **$880.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees.
A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **19-5425** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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March 9, 2000
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March 9, 2000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re\ Application of: John D. Holme

Based on Int'l Appln. No. PCT/GB98/02526
Filed August 21, 1998

Claiming Priority of GB 9718982.3
Filed Sept. 9, 1997

DISC BRAKE ROTOR WITH A GREY CAST IRON COMPOSITION

(Atty. Docket No. 23815 USA)

SECOND PRELIMINARY AMENDMENT

Assistant Commissioner
of Patents
Box PCT
Washington, DC 20231

Sir:

Please enter the following amendments after the grant of a filing date.

In the Claims

1 (amended). A disc brake rotor having a grey cast iron composition, [characterised in that] wherein said composition comprises between 0.5 and 1.2% by weight of copper, and a plurality of hard carbide forming metals including both vanadium and titanium, the ratio between the weight of copper present and the total weight of said hard carbide forming

metals being 1.8 to 3 units of copper to 1 unit of the one or more hard carbide forming metals.

2 (amended). A disc brake rotor according to claim 1, [characterised in that] wherein the hard carbide forming metals also include one or more of tungsten, molybdenum, chromium, and niobium.

3 (amended). A disc brake rotor according to claim 1, [characterised in that] wherein the weight of vanadium present in the composition is less than or equal to one half of the weight of copper present added to 20 times the weight of titanium present.

4 (amended). A disc brake rotor according to claim 1, [characterised in that] wherein the carbon equivalent of the composition is between 4.2 and 4.55.

5 (amended). A disc brake rotor according to claim 1, [characterised in that] wherein the titanium content of the composition is between 0.025 and 0.035%.

6 (amended). A disc brake rotor according to claim 1, [characterised in that] wherein the vanadium content of the composition is between 0.35 and 0.45 wt%.

7 (amended). A disc brake rotor according to claim 1, [characterised in that] wherein the copper content of the composition is between 0.7 and 0.9 wt%.

Please add the following claim.

--8. A disc brake rotor according to claim 2, wherein the weight of vanadium present in the composition is less than or equal to one half of the weight of copper present added to 20 times the weight of titanium present.--

Respectfully submitted,

SYNNESTVEDT & LECHNER LLP

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March 9, 2000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re\ Application of: John D. Holme

Based on Int'l Appln. No. PCT/GB98/02526
Filed August 21, 1998

Claiming Priority of GB 9718982.3
Filed Sept. 9, 1997

DISC BRAKE ROTOR WITH A GREY CAST IRON COMPOSITION

(Atty. Docket No. 23815 USA)

PRELIMINARY AMENDMENT TO REDUCE MULTIPLE
DEPENDENCIES PRIOR TO EXAMINATION OF THE APPLICATION

Assistant Commissioner
of Patents
Box PCT
Washington, DC 20231

Sir:

Please enter the following amendments after the grant of a filing date.

In the Claims

3 (amended). A disc brake rotor according to [either one of] claim[s] 1 [and 2], characterised in that the weight of vanadium present in the composition is less than or equal to one half of the weight of copper present added to 20 times the weight of titanium present.

4 (amended). A disc brake rotor according to [any one of] claim[s] 1 [to 3], characterised in that the carbon equivalent of the composition is between 4.2 and 4.55.

5 (amended). A disc brake rotor according to [any one of] claim[s] 1 [to 4], characterised in that the titanium content of the composition is between 0.025 and 0.035%.

6 (amended). A disc brake rotor according to [any one of] claim[s] 1 [to 5], characterised in that the vanadium content of the composition is between 0.35 and 0.45 wt%.

7 (amended). A disc brake rotor according to [any one of] claim[s] 1 [to 6], characterised in that the copper content of the composition is between 0.7 and 0.9 wt%.

Respectfully submitted,

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DISC BRAKE ROTOR WITH A GREY CAST IRON COMPOSITION

This invention is concerned with a disc brake rotor.

A disc brake rotor is arranged to rotate with a member, such as a wheel of a vehicle or a rotating part of a machine. Such a rotor provides two oppositely-facing annular friction surfaces which, in the operation of the brake, are engaged by blocks of friction material to decelerate the rotor and hence the member. Two of the friction material blocks are moved (usually by hydraulic means) towards one another into contact with the two friction surfaces so that frictional forces occur slowing the rotation of said rotor, and hence of said member.

In selecting a material for a disc brake rotor, it is necessary to consider the coefficient of friction of the material and its thermal properties, since considerable heat is generated during braking. Conventionally, disc brake rotors for passenger vehicles have been made from unalloyed grey irons consisting of flake graphite in a pearlitic matrix. These have carbon contents in the range 3.25-3.55 wt% and strength levels are typically approximately 220 MPa. In order to increase thermal conductivity, the carbon level can be increased to 3.65-3.95 wt% but this decreases the strength, eg to approximately 150 MPa. Increased carbon levels also may result in microstructural defects so that casting difficulties are increased.

It is well known to alloy the higher carbon-containing irons with matrix strengthening elements such as chromium, molybdenum, nickel and vanadium in order to increase the strength. For example, WO 96/07766 discloses a pearlitic grey iron which comprises 3.5-3.7 wt% carbon, 1.9-2.05 wt% silicon, 0.05-0.1 wt% vanadium, 0.2-0.3 wt% molybdenum, 0.2-0.3 wt% chromium and 0.2-0.3 wt% copper. EP 0778355 A discloses a grey cast iron for brake discs containing 3.65-3.95 wt% carbon, 1.8-2.2 wt% silicon, 0.2-0.4 wt% chromium,

0.2-0.8 wt% niobium and 0.3-0.5 wt% copper. However, alloying has a detrimental effect on thermal conductivity.

In addition to thermal and mechanical considerations, a material for a disc brake rotor must exhibit good wear resistance. In an unalloyed iron, wear resistance is primarily a function of the matrix structure and its hardness. Alloying the iron can create carbides so that wear resistance becomes more a function of the properties of the carbides. However, when vanadium, titanium and chromium are added to iron in excess quantities, a fall in the strength occurs arising from the formation of inter-granular carbides in the matrix. Carbide stabilising elements such as chromium, molybdenum and vanadium also increase the tendency for the formation of free ferrite which is detrimental to the strength and tribological properties. For this reason, these elements are normally used at levels which are below those at which free carbides are formed so that the wear benefits of free carbides are not obtained. It is also considered that the use of high alloy structures containing free carbides would cause the formation of "hot spots" resulting in brake judder and heat cracking.

The present invention has the object of further increasing the thermal fatigue and wear resistance properties of a disc brake rotor.

The invention provides a disc brake rotor having a grey cast iron composition, characterised in that said composition comprises between 0.5 and 1.2% by weight of copper, and a plurality of hard carbide forming metals including both vanadium and titanium, the ratio between the weight of copper present and the total weight of said hard carbide forming metals being 1.8 to 3 units of copper to 1 unit of the hard carbide forming metals.

AMENDED SHEET

In a disc brake rotor according to the invention improved thermal fatigue and wear resistance properties are achieved by a careful balance of the additives which, on the one hand, avoids a detrimental microstructure with inter-granular carbide eutectic phases and, on the other hand, gives higher wear resistance. The hard carbide forming metals can also include one or more of tungsten, chromium, molybdenum, and niobium. Where chromium is included, preferably, it is at a maximum of 0.05 wt%.

It has previously been recognised that titanium levels can have a critical effect on the co-efficient of friction and wear characteristics of a cast iron disc brake rotor. Levels below 0.1 wt% promote "graphitisation" and form hard discrete particles of titanium carbonitride. Such particles dramatically increase wear performance but, above 0.05 wt% of titanium, the rotors become difficult to machine, bedding-in of the rotor is very slow, and the friction material wear is increased. In order to avoid these problems, preferably, in a disc brake rotor according to the invention, the composition comprises both vanadium and titanium with the weight of vanadium present being less than or equal to one half of the weight of copper present added to 20 times the weight of titanium present. By this careful selection of titanium, vanadium and copper improved wear and frictional properties can be achieved without the problems of hot-spotting and manufacturing difficulties.

Preferably, in a disc brake rotor according to the invention, the carbon equivalent of the composition is between 4.2 and 4.55, the titanium content of the composition is between 0.025 and 0.035 wt%, the vanadium content of the composition is between 0.35 and 0.45 wt%, and the copper content of the composition is between 0.7 and 0.9 wt%.

There now follow detailed descriptions of two disc brake rotors which are illustrative of the invention.

The first illustrative disc brake rotor has a grey cast iron composition. In order to form the first illustrative disc brake rotor a base cast iron composition was alloyed. The base iron composition was as follows:

carbon 3.65 wt%, silicon 2.10 wt%, phosphorus 0.06 maximum, manganese 0.65 wt%, sulphur 0.10 wt%, nickel residual, and the balance iron. This gave a carbon equivalent of 4.2 to 4.37.

It is considered that practical limits for the base grey iron are:

carbon 3.5-3.8, silicon 2.00-2.20, phosphorus 0.10 maximum, manganese 0.60-0.80, and sulphur 0.15 maximum.

To the base composition, alloying materials were added to give a vanadium content of 0.35 wt%, a titanium content of 0.025 wt%, a chromium content of 0.05 wt% maximum, and a copper content of 0.8 wt%. It should be noted that the composition comprises hard carbide forming metals (vanadium and titanium) which at 0.375 wt% is less than half of the copper content at 0.8 wt%. Thus, the ratio between the weight of copper present and the weight of the hard carbide forming metal is 2.13 units of copper to 1 unit of the hard carbide forming metal.

It should also be noted that the vanadium and titanium present satisfies the formula that the weight of the vanadium present (0.35 wt%) is less than one half of the weight of the copper present added to 20 times the weight of titanium present (0.8 wt% of copper divided by 2 gives 0.4 wt% plus 20 times 0.025 wt% equals 0.9wt%).

The first illustrative rotor was compared in wear tests with a comparison rotor made of a conventional base

grey cast iron used for disc brake rotors. This cast iron has a composition of:

carbon 3.42 wt%, silicon 2.37 wt%, manganese 0.65 wt%, sulphur 0.09 wt%, phosphorus 0.04 wt%, chromium 0.3 wt%, titanium 0.03 wt% and the balance iron.

In a wear test at low pressure, the wear on the first illustrative rotor was 69% of that of the comparison rotor. In a medium pressure wear test, the wear on the first illustrative rotor was 57% of that of the comparison rotor. In a high pressure wear test, the wear on the first illustrative rotor was 71% of that of the comparison rotor. In the same tests, the wear on the friction material pads running against the first illustrative rotor was 79%, 88%, and 89%, respectively, compared to the wear on the friction material pads running against the comparison rotor.

The first illustrative rotor was also compared with the comparison rotor in a thermal fatigue resistance test, ie a test in which the materials were stressed cyclically to pre-determined stress levels at various temperatures and the number of cycles to failure were measured. The first illustrative rotor consistently achieved superior results to the comparison rotor, eg at 250°C, at a stress level of 75 MPa the comparison rotor failed at 18,000 cycles whereas the first illustrative rotor failed at 282,000 cycles, and, at a stress level of 70 MPa, the comparison rotor failed at 63,000 cycles whereas the first illustrative rotor failed at 1,122,000 cycles.

The second illustrative disc brake rotor has a grey cast iron composition. Said composition is 3.53 wt% carbon, 2.04 wt% silicon, 0.63 wt% manganese, 0.1 wt% sulphur, 0.06 wt% phosphorus, 0.29 wt% chromium, 0.79 wt% copper, 0.011 wt% titanium, 0.10 wt% vanadium, and the balance iron. Thus, the hard carbide forming metals (chromium, titanium and vanadium total 0.401 wt% so that

the ratio between the weight of copper present and the weight of said hard carbide forming metals is 1.97 units of copper to 1 unit of the hard carbide forming metals.

The second illustrative rotor was compared in wear tests with a comparison rotor made of a conventional base grey cast iron described above. In a medium pressure wear test, the wear on the second illustrative rotor was 79% of that of the comparison rotor, and the wear on the friction material pads was 84% of that of the pads running against the comparison rotor.

CLAIMS

1 A disc brake rotor having a grey cast iron composition, characterised in that said composition comprises between 0.5 and 1.2% by weight of copper, and a plurality of hard carbide forming metals including both vanadium and titanium, the ratio between the weight of copper present and the total weight of said hard carbide forming metals being 1.8 to 3 units of copper to 1 unit of the hard carbide forming metals.

2 A disc brake rotor according to claim 1, characterised in that the hard carbide forming metals also include one or more of tungsten, molybdenum, chromium, and niobium.

3 A disc brake rotor according to either one of claims 1 and 2, characterised in that the weight of vanadium present in the composition is less than or equal to one half of the weight of copper present added to 20 times the weight of titanium present.

4 A disc brake rotor according to any one of claims 1 to 3, characterised in that the carbon equivalent of the composition is between 4.2 and 4.55.

5 A disc brake rotor according to any one of claims 1 to 4, characterised in that the titanium content of the composition is between 0.025 and 0.035 wt%.

6 A disc brake rotor according to any one of claims 1 to 5, characterised in that the vanadium content of the composition is between 0.35 and 0.45 wt%.

AMENDED SHEET

7 A disc brake rotor according to any one of claims 1 to 6, characterised in that the copper content of the composition is between 0.7 and 0.9 wt%.

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International Appln. No. PCT/GB98/02526
Atty. Docket 23815 USA

ABSTRACT

A disc brake rotor having a grey cast iron composition. Said composition comprises between 0.5 and 1.2% by weight of copper, and a plurality of hard carbide forming metals, including both vanadium and titanium. The ratio between the weight of copper present and the weight of said hard carbide forming metals is 1.8 to 3 units of copper to 1 unit of the hard carbide forming metals.

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Docket No.
23815 USA

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 21 August 1998 as United States Application No. or PCT International Application Number PCT/GB98/02526

and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
9718982.3	Great Britain	9 September 1997	☐
(Number)	(Country)	(Day/Month/Year Filed)	
			☐
(Number)	(Country)	(Day/Month/Year Filed)	
			☐
(Number)	(Country)	(Day/Month/Year Filed)	

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112. I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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Gregory S. Bernabeo, Reg. No. 44,032	John T. Synnestvedt, Reg. No. 18,~~117~~
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Full name of sole or first inventor
JOHN DAVID HOLME

Sole or first inventor's signature — Date
David Holme — 21/2/00

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Full name of second inventor, if any

Second inventor's signature — Date

Residence

Citizenship

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